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# **Traffic Monitoring Using Solar Power**

**North American Travel Monitoring Exhibition and  
Conference**

**May 14, 2002**

***Florida Solar Energy Center***

***A Research Institute of the University of Central Florida***



# Why Solar?

- ◆ No Power Lines
  - \$10K-\$40K / Mile
- ◆ No Generator
  - Quiet Operation
  - No Refueling

◆ Portable

◆ Reliable - *When Properly Designed and Installed!*





# *What NOT to do!*

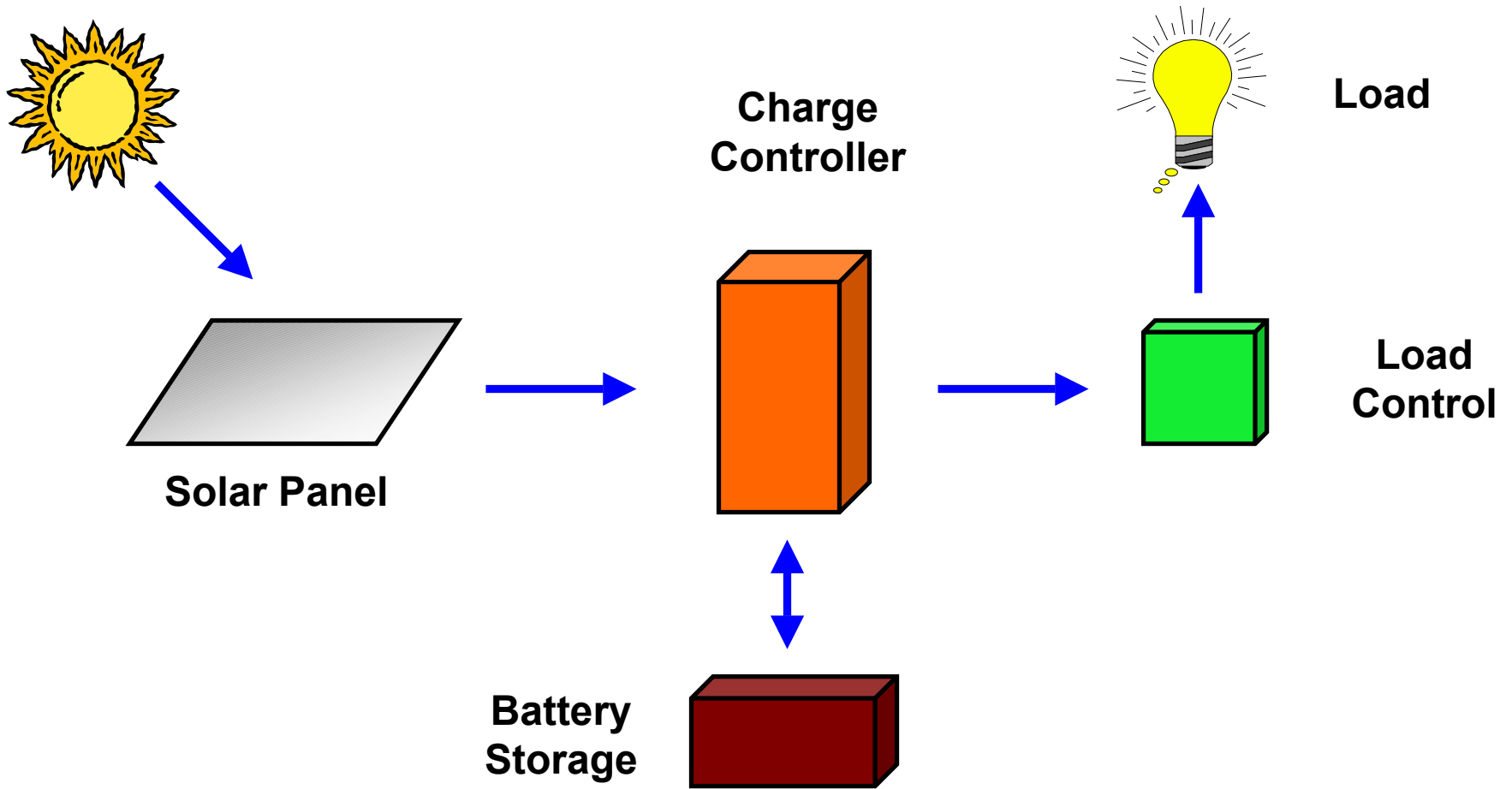
## **Traffic Counter**

**SR-528 near the  
SR-520 exit**



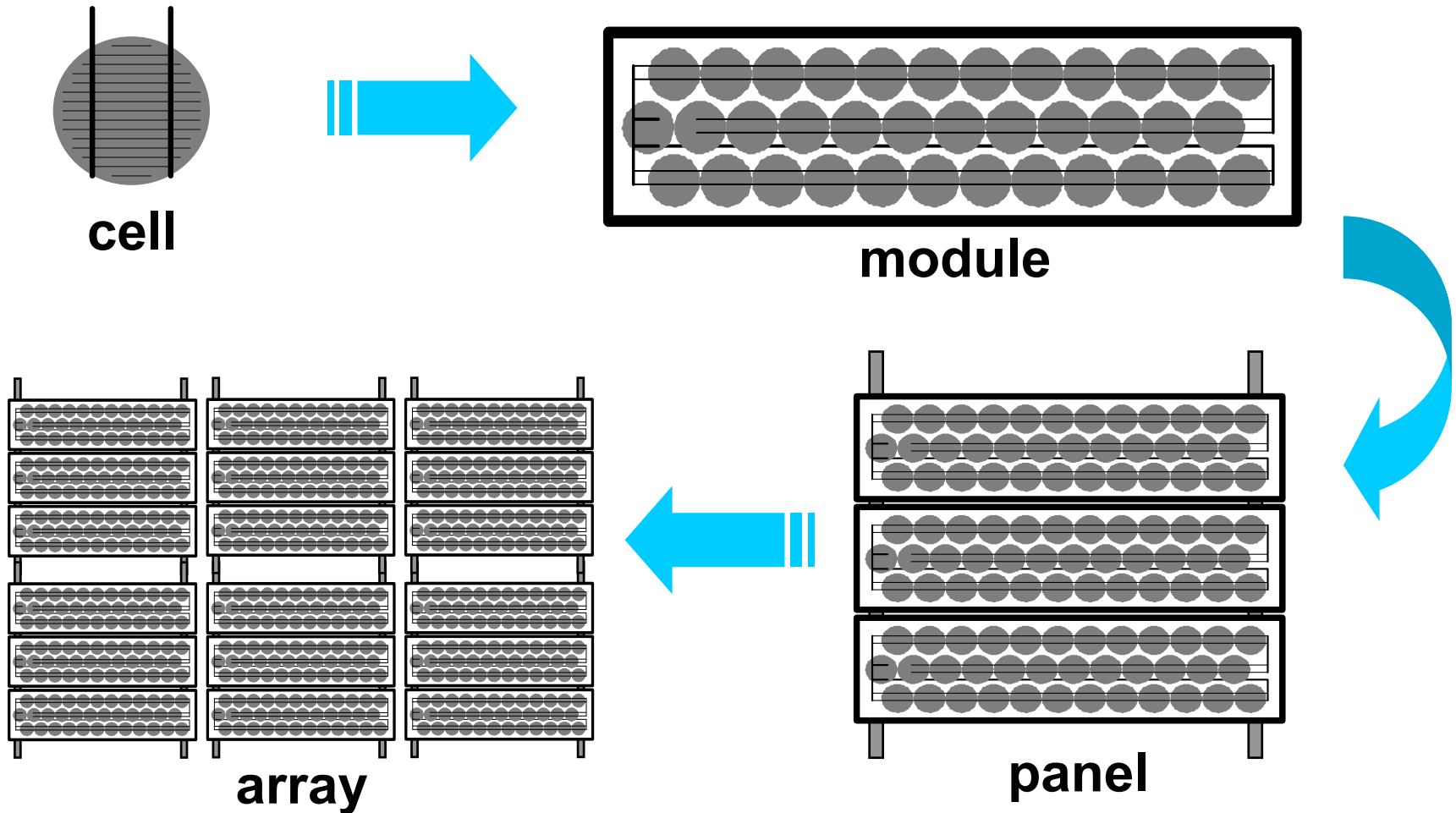


# PV System Components



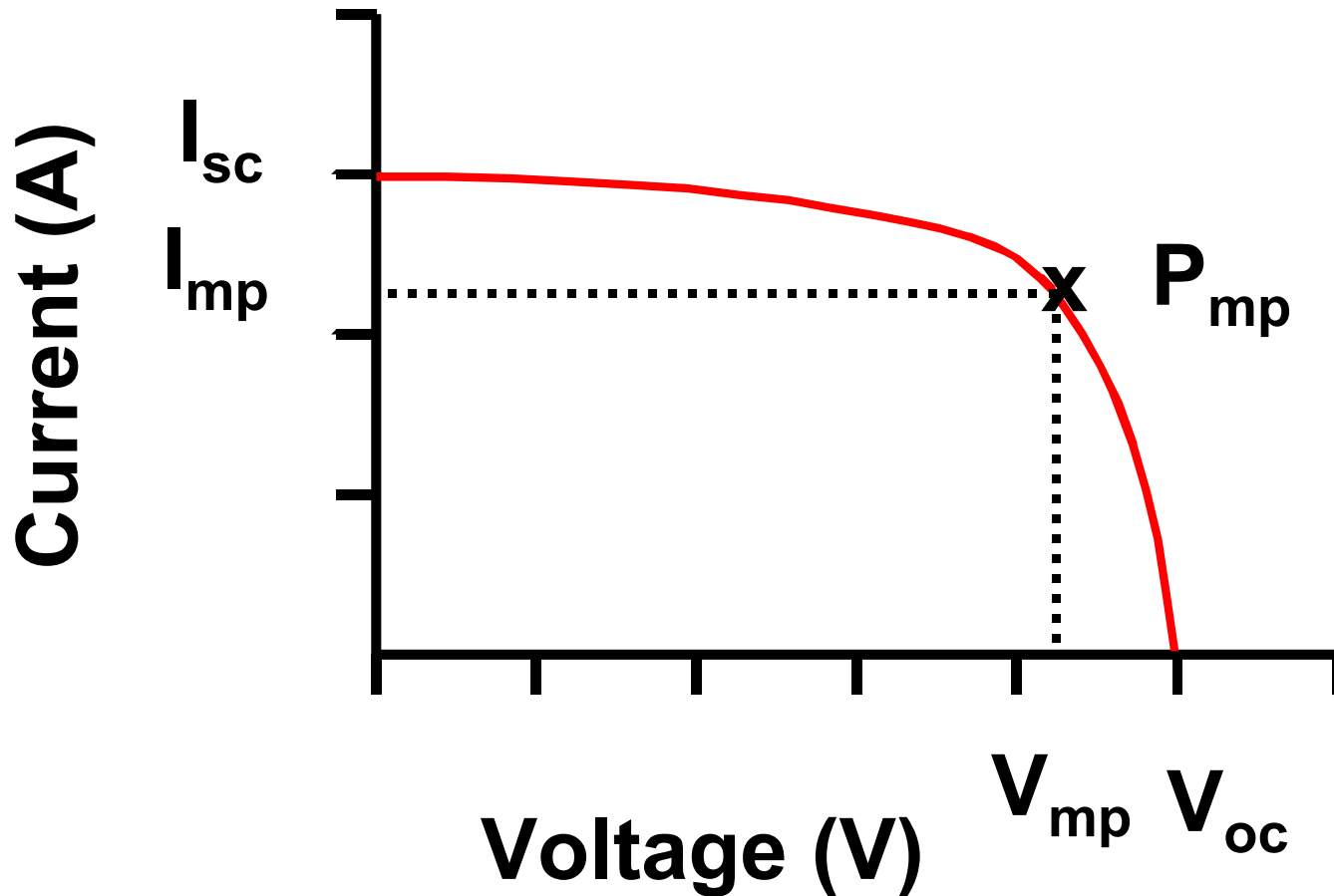


# *Photovoltaic Cells, Modules, Panels and Arrays*





# *PV Module Performance Parameters I-V Curves*





# Typical Module Label

## Siemens Solar Industries

Camarillo, CA 93011

MODEL M55  
PHOTOVOLTAIC MODULE  
AT 1000 W/M<sup>2</sup> SOLAR IRRADIANCE  
AND 25°C CELL TEMPERATURE



30B9 LISTED

MAX. POWER

53 WATTS

SHORT CKT.

3.35 A

RATED

3.05 A

MAX. SYST. OPEN CKT. V.

600 VOLTS

OPEN CKT.

21.7 V

RATED

17.4 V

FIRE RATING

CLASS C

SERIES FUSE

5 A

FIELD WIRING

COPPER ONLY, 14 AWG MIN.  
INSULATED FOR 75 °C MIN.

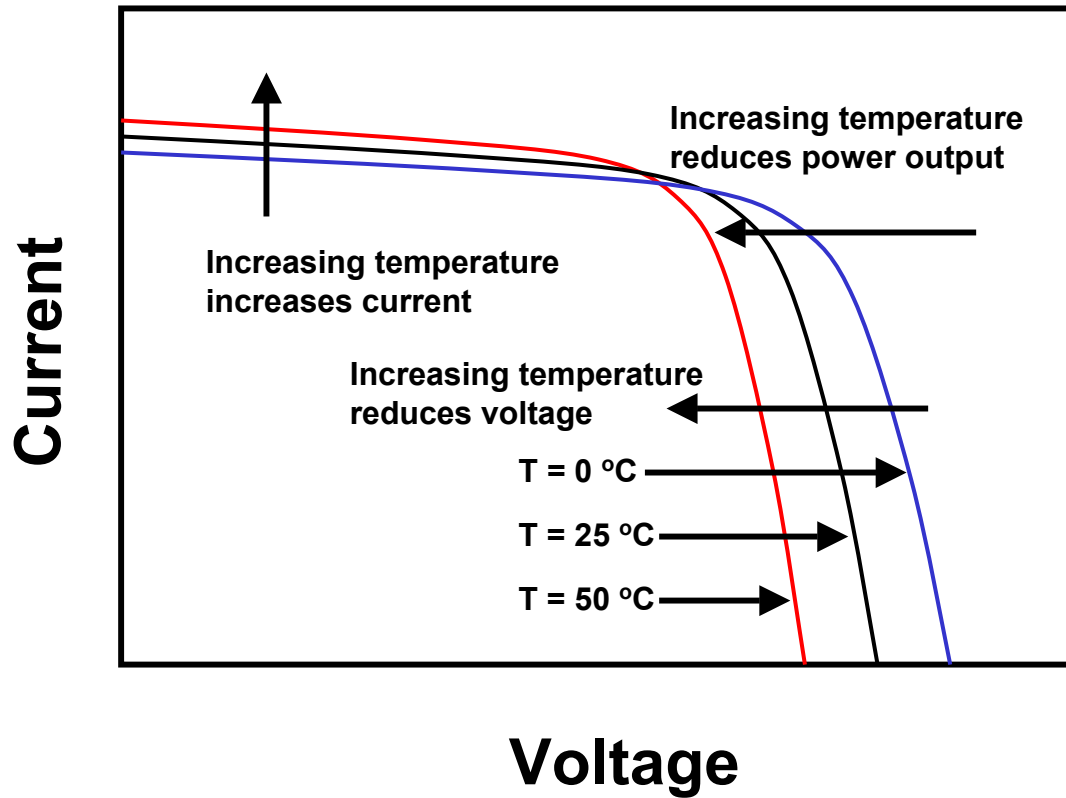
BYPASS DIODE

INSTALLATION GUIDE  
233-701500-20

MADE IN U.S.A.

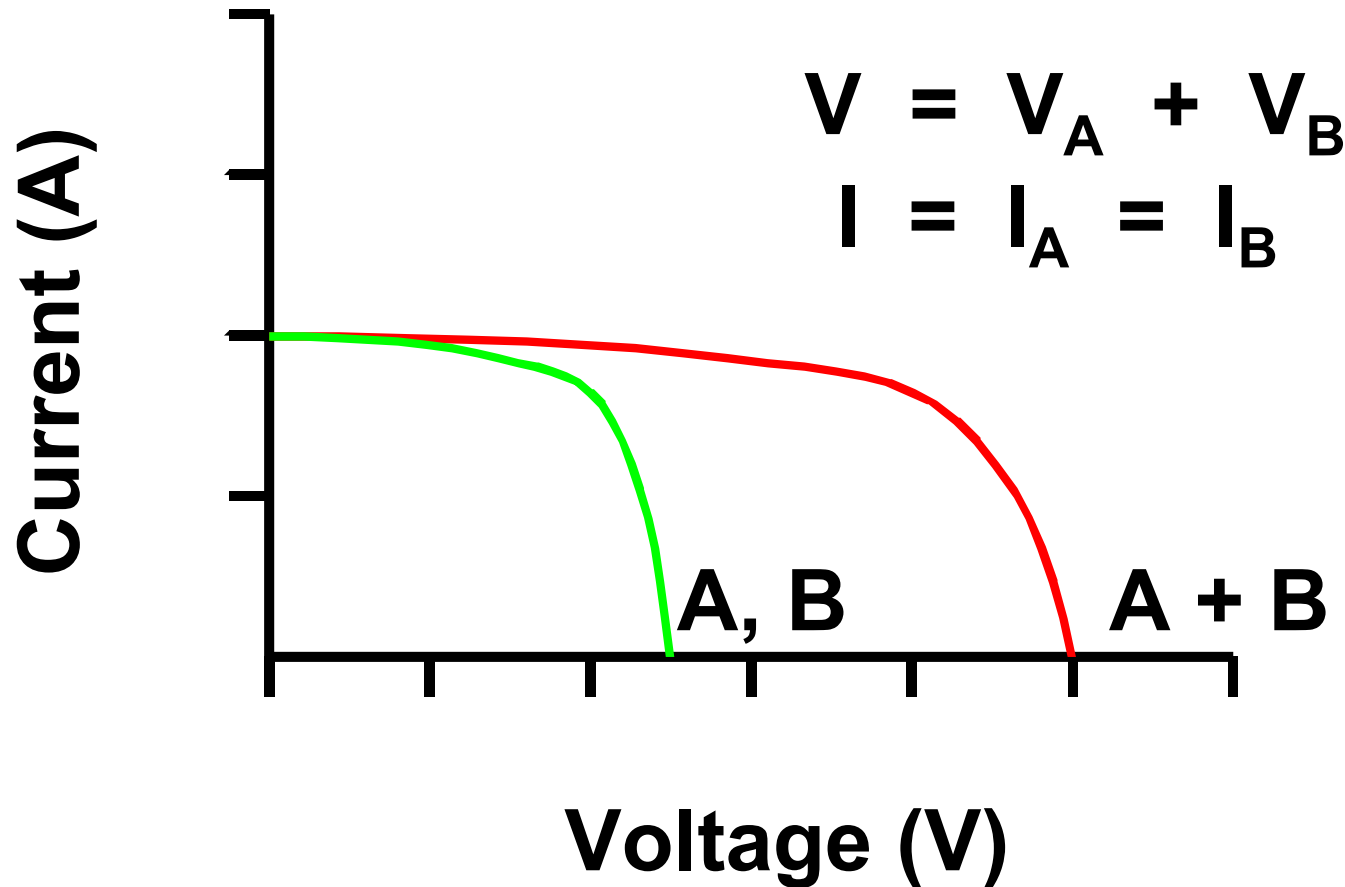


# Response to Temperature



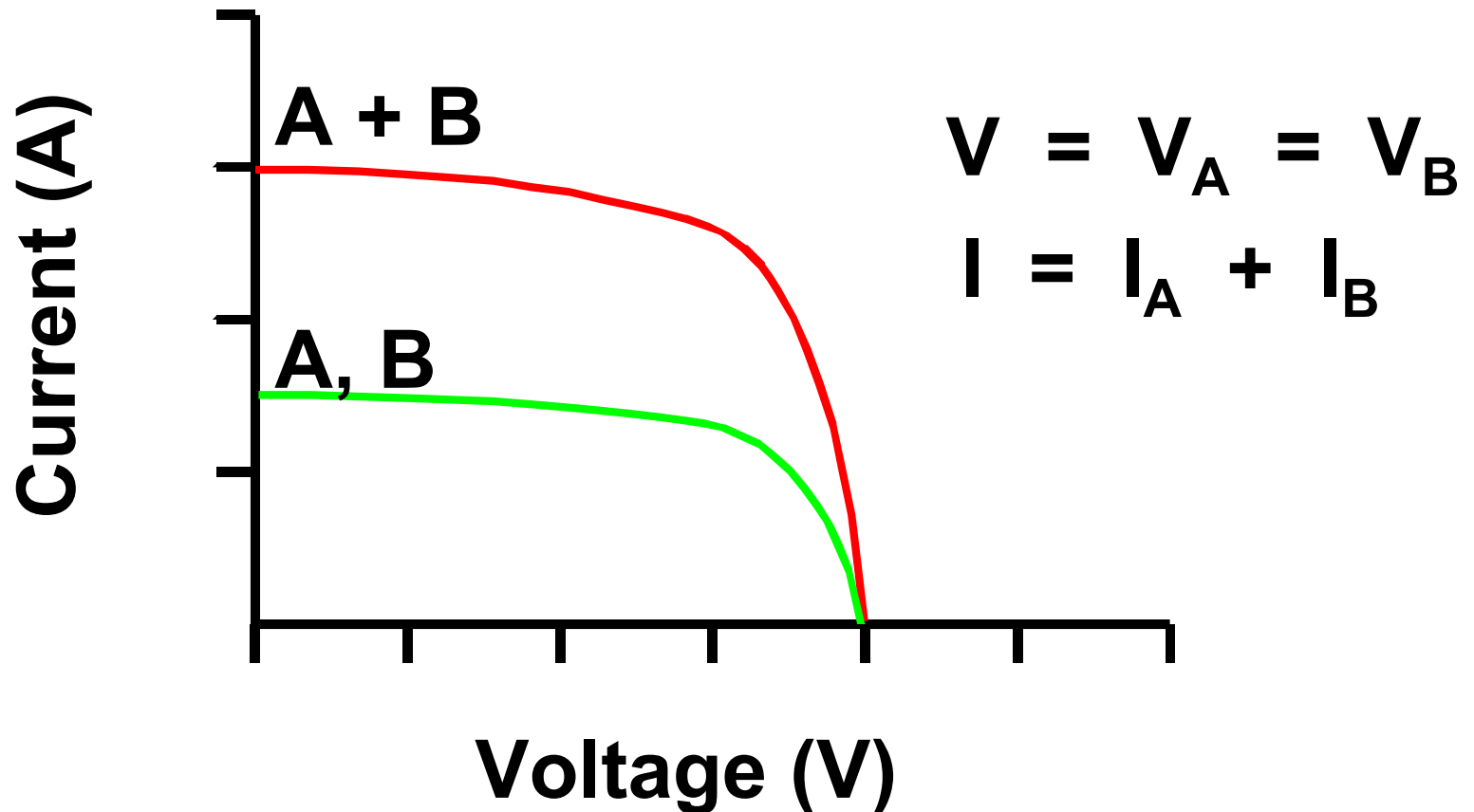


# *I-V Curves for Series Devices*



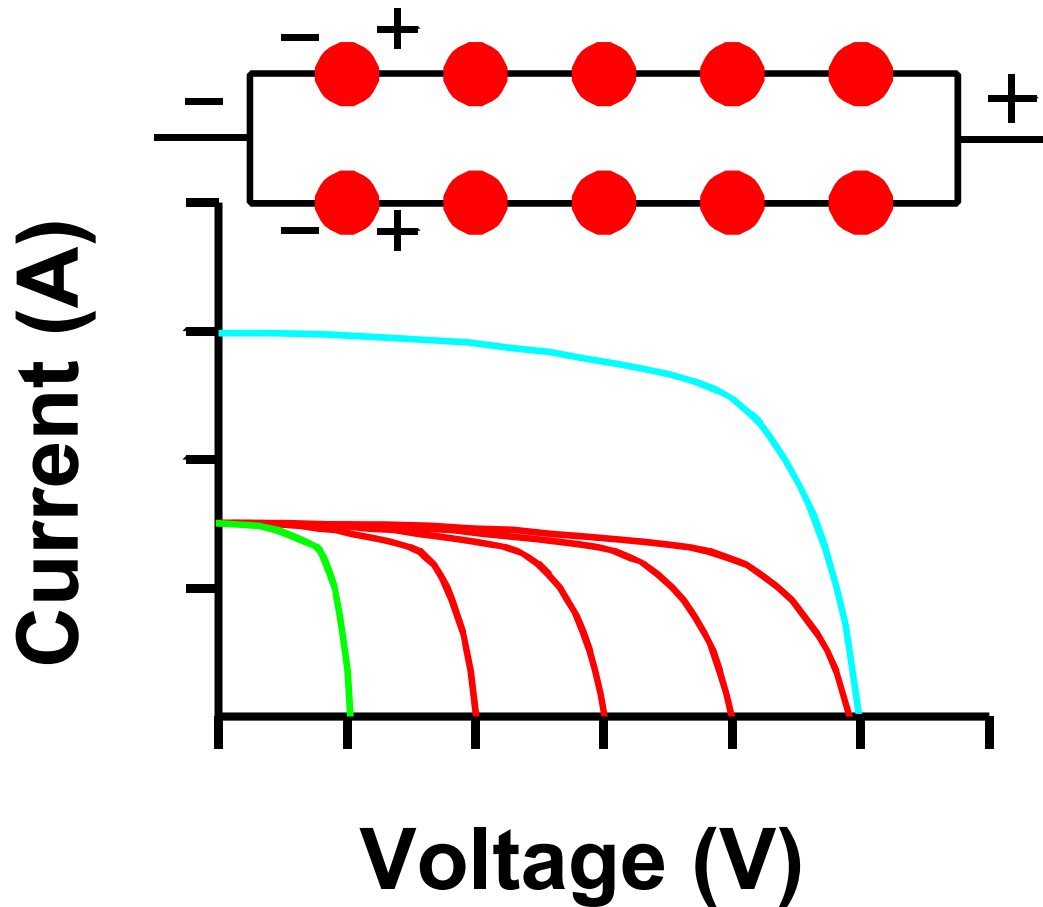


# *I-V Curves for Parallel Devices*





# Building a PV Array





# *Protection Diodes*

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- ◆ Diodes are semiconductor devices that allow current to flow in only one direction.
- ◆ The two uses of diodes in PV array design are:
  - Blocking diodes - Night-time Protection
  - Bypass diodes - Shading Protection



# Blocking Diodes

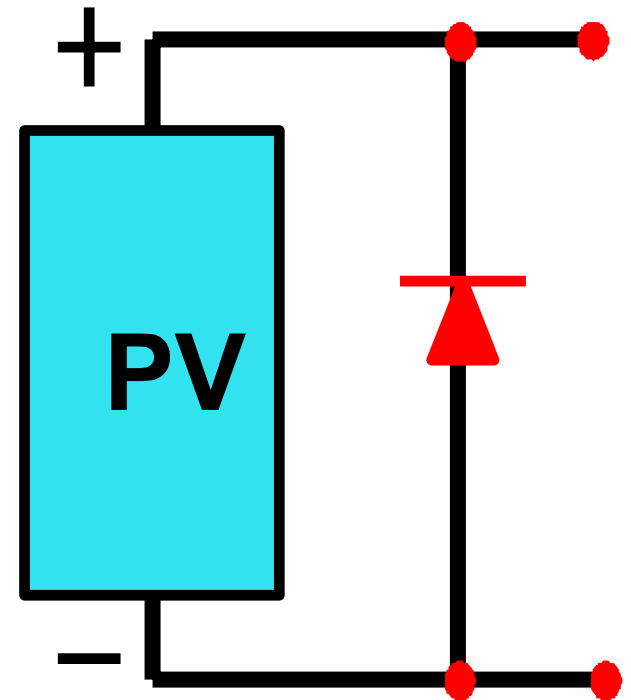
- ◆ Placed in series with a module to prevent reverse current flow.
- ◆ Prevent discharge of batteries at night in stand-alone systems.





# Bypass Diodes

- ◆ Permits other parts of the array to pass current *around* groups of cells or modules that develop an *open-circuit* or *high resistance* condition.





# Charge Controller

- ◆ Battery Voltage Regulation
- ◆ Over-charge Protection
- ◆ Low Voltage Disconnect
- ◆ Multiple settings for different battery types
- ◆ Max Power Tracking





# Battery Types

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- ◆ Flooded Lead-Acid
  - Can handle deep discharge
  - Requires periodic maintenance
- ◆ Valve Regulated
  - Requires proper charge control
- ◆ Ni-Cd
  - High Cost



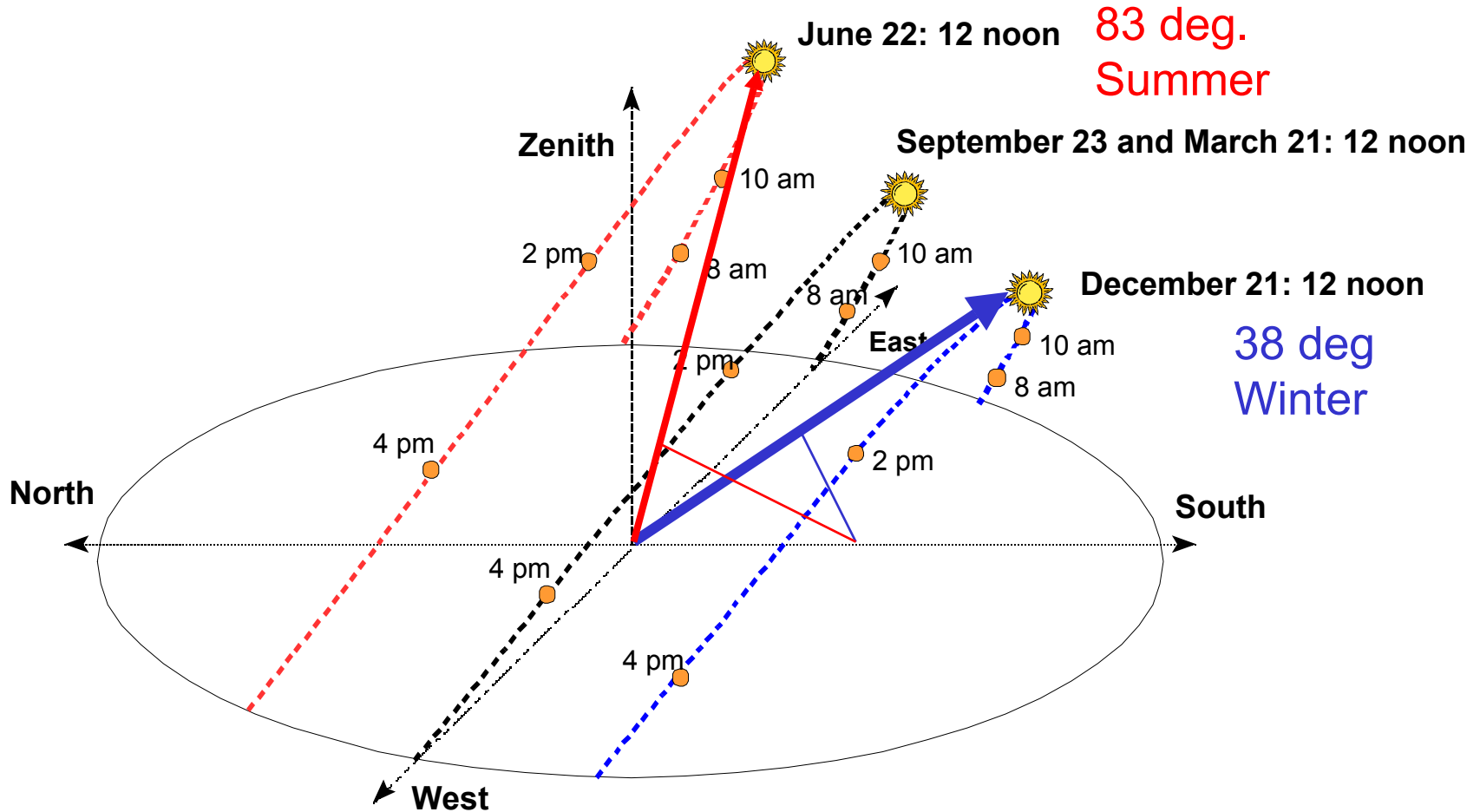
# *System Design*

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- ◆ Location and Mounting
  - Sun Angle and Shading
  - Array Tilt Angle
- ◆ System Sizing
  - Load
  - Battery
  - PV Array



# Sun Paths for 30° N Latitude





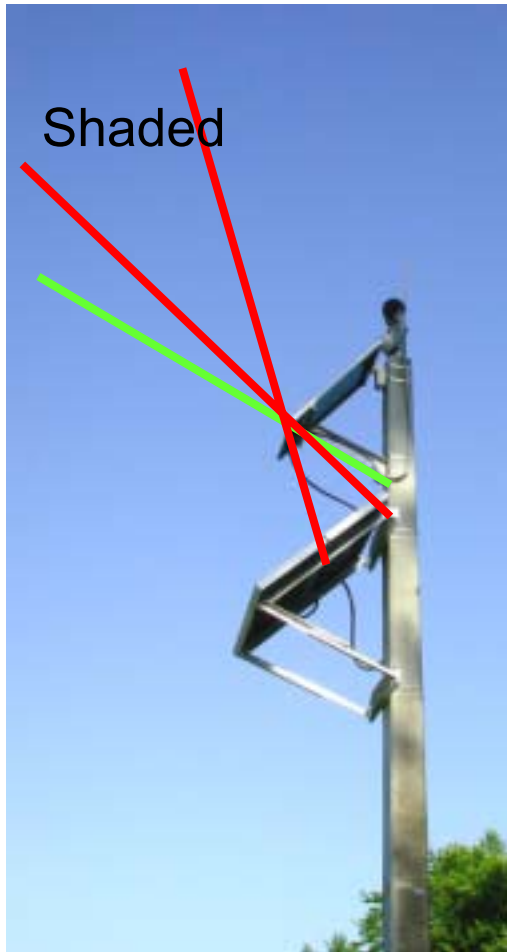
# Array Orientation

- ◆ Array facing directly South receives maximum sun hours





# Array Layout and Sun Angle





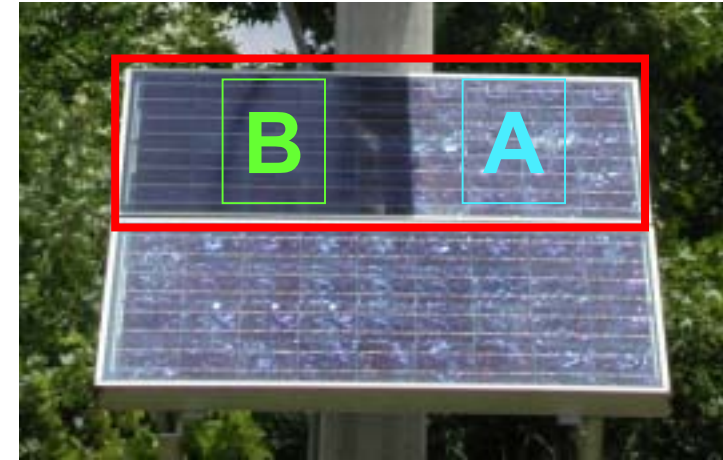
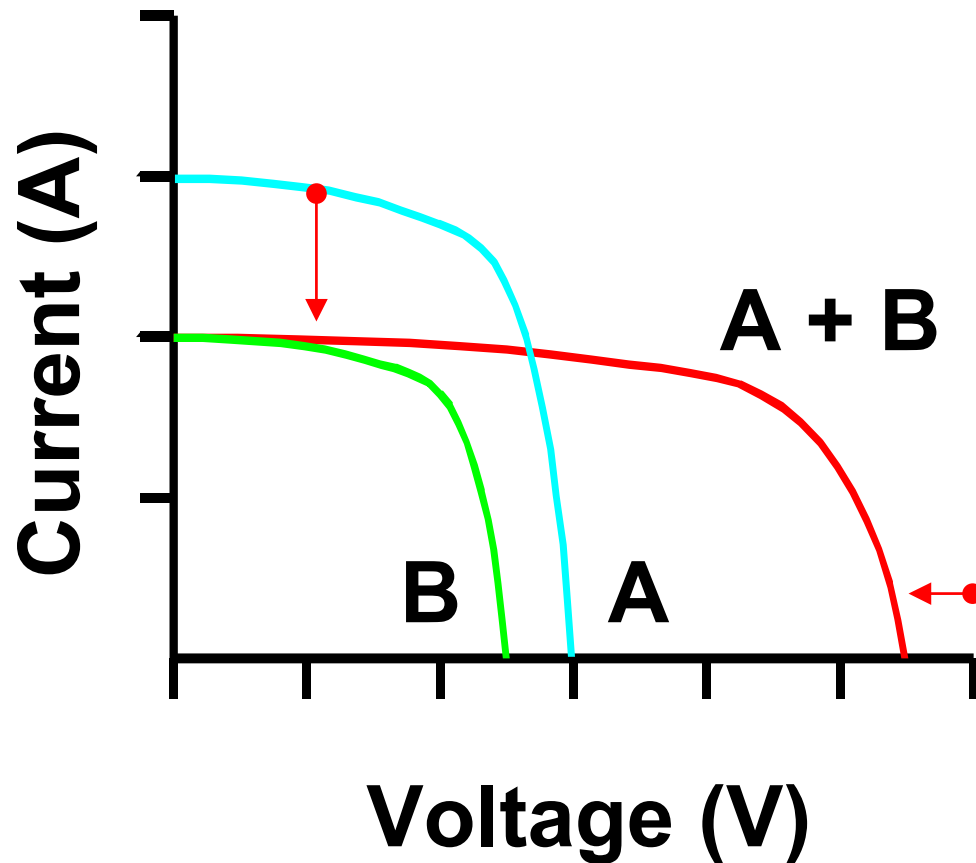
# Shading

- ◆ Reduces Power Output
  - Limits Current in series connections
- ◆ Can damage cells without bypass diodes





# *I-V Curves for Shaded PV Devices in Series*

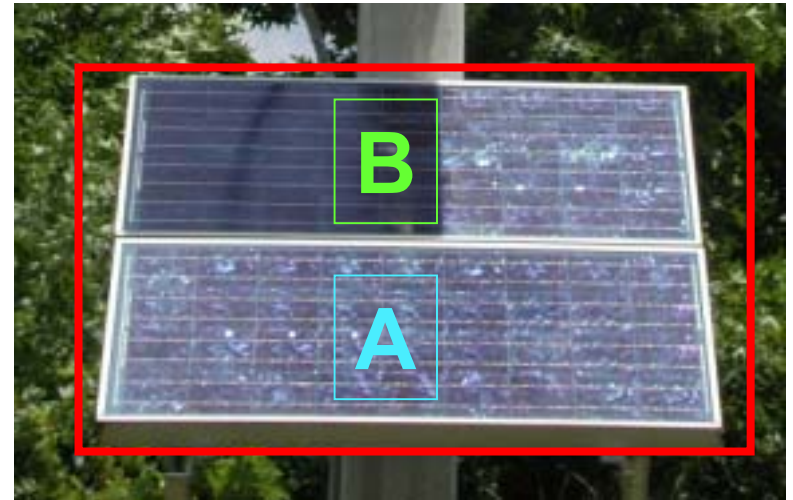
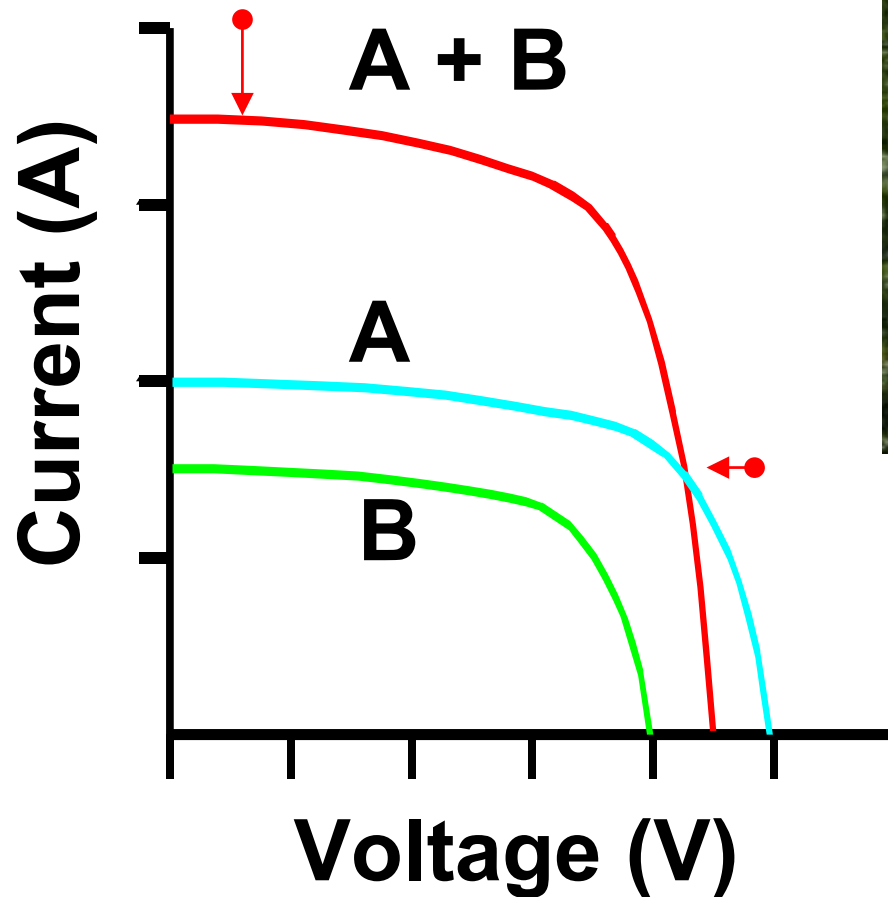


$$V = V_A + V_B$$

$$I = I_B < I_A$$



# *I-V Curves for Shaded PV Devices in Parallel*



$$V = (V_A + V_B)/2$$

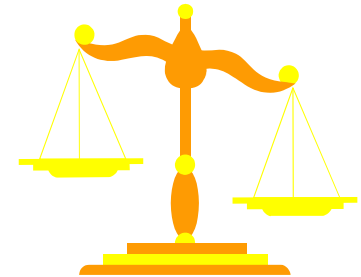
$$I = I_A + I_B$$



# ***PV Array and Battery Sizing***

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- ◆ The size and configuration of a given PV array is determined by:
  - Load or desired output
  - Available solar insolation
  - Array tilt angle
  - Individual module characteristics.





# ***Load Characteristics***

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- ◆ Time of Use
  - Continuous or Periodic
- ◆ Importance of operation
  - Critical Loads
- ◆ Average Power vs Peak Power
- ◆ Component Voltage requirements



# Time of Use

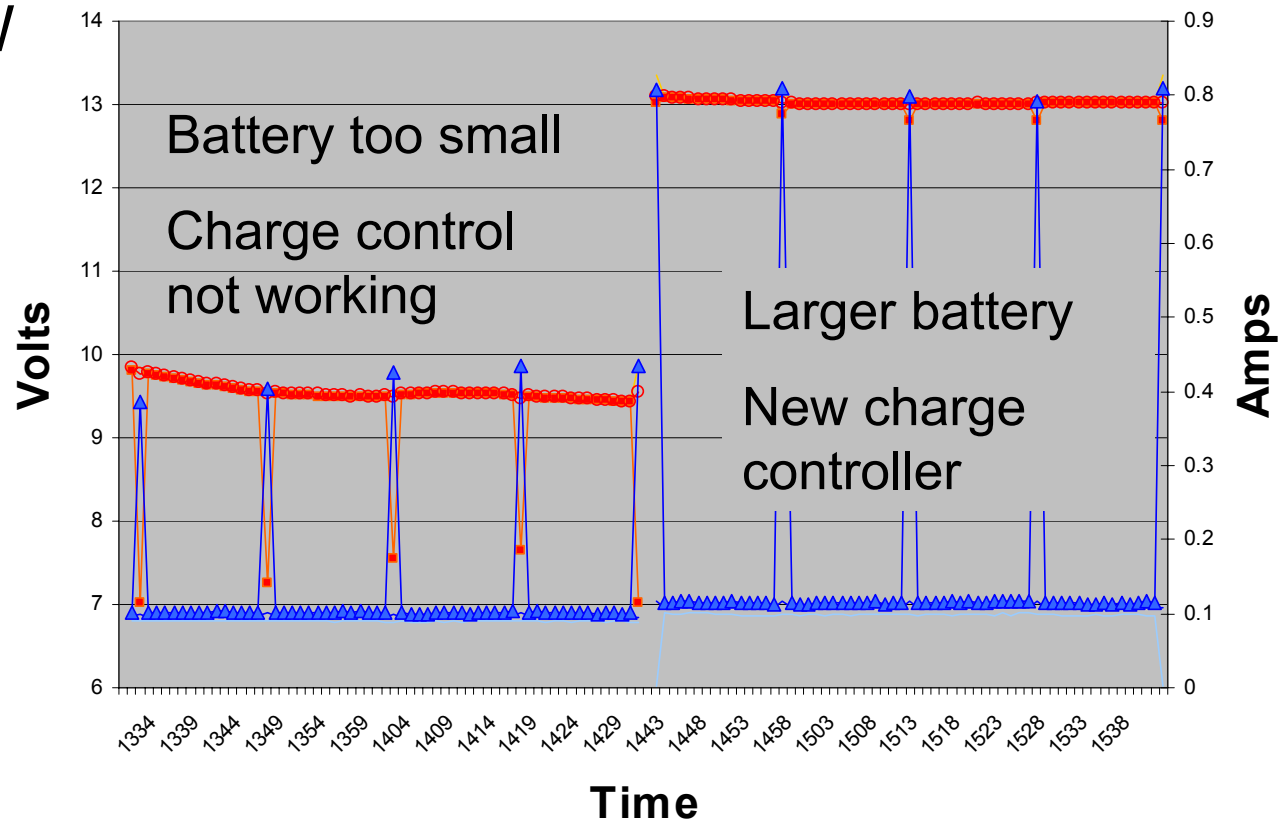
FSEC

Paccomm Weather Station Power

Idle Power = 1 W

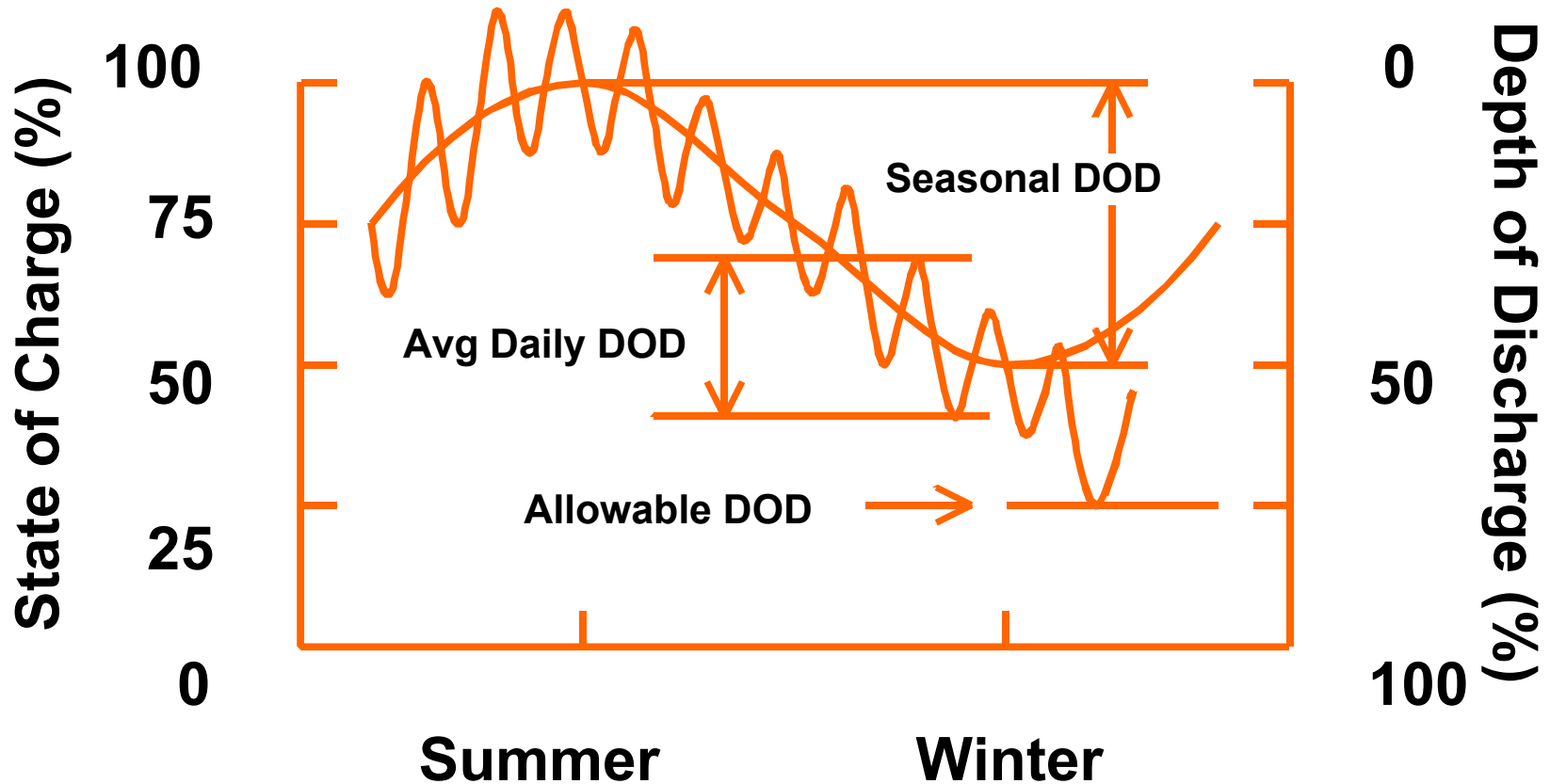
Peak Power =  
3.3 W vs 10.4 W

1 Second Data  
Transmit every  
15 Minutes





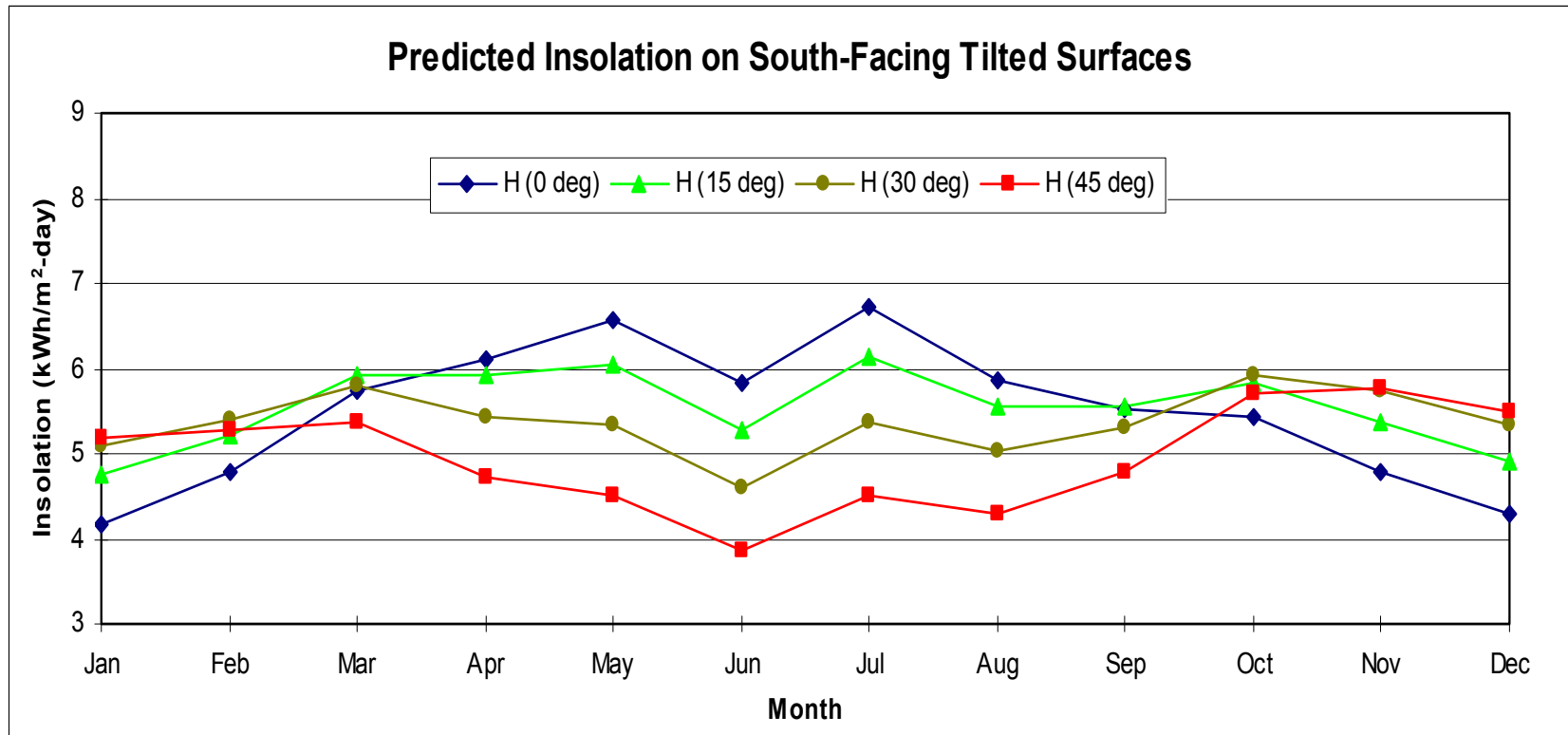
# Battery State of Charge





# Solar Insolation - Array Tilt

## Orlando, Florida





# *Array Tilt*

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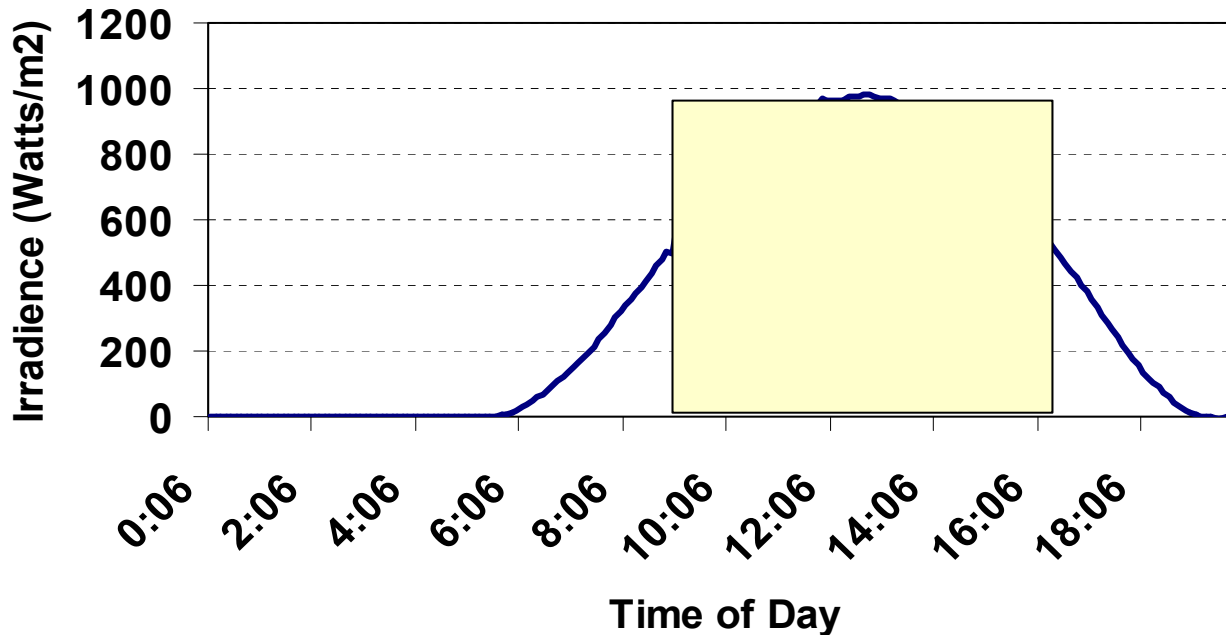
<i><u>Application</u></i>	<i><u>Best Array Tilt Angle</u></i>
◆ Maximum Annual Energy Production	90% of Latitude
◆ Winter Peak Load	Latitude plus 15 degrees
◆ Summer Peak Load	Latitude minus 15 degrees



# *Sun-Hours from Insolation Data*

## Typical Florida Day

Area in box = Area under curve



7.25 Peak  
Sun-Hours

◦ **Peak Sun Hours  $\Rightarrow$  Equivalent amount of insolation (energy) at 1000 W/m<sup>2</sup>**



# *Example Load Calculations*

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## ◆ Traffic Counter

- 24 Hour Monitoring
- 12V Counter Circuit

## ◆ School Warning Light

- 2 hours in the morning and afternoon
- 24V Light



# ***Load Calculations***

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## ◆ Counter:

- 10 Watt Continuous
- 240 Watt-hours / Day
- 12V = 20 Amp-hours / Day

## ◆ Warning Light:

- 60 Watts - 4 Hours / Day
- 240 Watt-hours/Day
- 24V = 10 Amp-hours/Day



# *Days of Autonomy*

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## ◆ How long can the system run without sunlight?

- Critical or Safety Load: 4-6 Days
- Non-critical Load: 1-3 Days

## ◆ Counter:

- $20 \text{ Ahrs/day} * 2.5 \text{ days} = 50 \text{ Ahrs}$

## ◆ Warning Light:

- $10 \text{ Ahrs/day} * 5 \text{ days} = 50 \text{ Ahrs}$



# Battery Sizing

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- ◆ 50 Ahrs = Maximum Discharge of 70%
  - $50 / 0.7 = 70$  Ahr Battery
- ◆ Counter:
  - One 70 Ahr 12V Battery
- ◆ Light:
  - Two 70 Ahr 12 V Batteries in Series



## *PV Sizing*

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- ◆ 240 Whrs / Day
- ◆ 5 Sun-hours/day = 48 Watts PV
- ◆ Add 25% for losses in battery charging
- ◆  $48W \times 1.25 = 60W$  PV
  - Counter = Two 30W 12V modules in parallel
  - Light = Two 30 W 12V modules in series



# Summary

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- ◆ Location:
  - Clear view of south sky
  - Average sun-hours available
- ◆ Battery Sizing:
  - Total daily load x days of autonomy
  - Maximum depth of discharge
- ◆ PV Sizing:
  - Daily load + efficiency losses

